Cancer Risks Associated with Employment as a Radiological Technologist

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Radiological technologists represent a unique occupational group with low-dose and low-dose-rate radiation exposure. Small and large cohorts of radiological technologists and other radiation workers have been assembled in Denmark, Japan, China, Canada and the U.S. that have been followed for cancer mortality and incidence. Women comprise variable proportions (range 20 to 82%) of the cohorts in Denmark, China, Canada and the U.S. We summarize here reported findings from the cancer mortality and incidence studies. Many cohorts have been updated recently and we have chosen to focus on the most recently published findings. In the case of the U.S. radiological technologists, we present selected published and unpublished data on cancer mortality and incidence.

Cancer Mortality Studies in Radiological Technologists

One of the earliest studies assessed cancer and other mortality risks among male radiological technologists ($n = 6{,}560$) serving in the U.S. Army during World War II. For comparison, men working as technologists in medicine or pharmacology or in a laboratory ($n = 6{,}826$) were also followed. Over the period 1946–1974, Jablon and Miller (*1*) found no differences in deaths from cancer or other causes in this cohort. Even though the mid-1940s was a period when work-related medical radiation exposures were relatively high, the exposure duration was short (averaging less than 3 years), suggesting that the average cumulative exposure was probably low.

A cohort of Japanese male radiological technologists assembled from licensing records ($n = 12{,}195$) was followed for 25 years, from 1969 to 1993 (*2*). Their cancer mortality experience was compared to corresponding cancer mortality rates in the general population of Japanese men and to a subgroup of Japanese men employed in professional/technical jobs. The calendar periods when the Japanese technologists worked are not known with complete certainty because licensing regulations were not instituted until 1968; many had presumably worked in previous years. Therefore, the cohort was divided, with the more highly exposed cohort comprised of radiological technologists born in 1933 or before and the second cohort born after 1933. Among those born prior to 1934 ($n = 4{,}595$), nonsignificant excess risks of death were observed for colon cancer, lymphoma, multiple myeloma and leukemia. Significant deficits were observed for all solid cancers combined and for cancers of the stomach and lung. The Japanese technologists who were born before 1934 likely worked variable amounts of time in the earlier calendar periods when occupational exposure to radiation was high and personal exposure was not monitored.

Using certification records of the American Registry of Radiologic Technologists, 143,517 U.S. technologists (73% female) certified for 2 or

more years during 1926–1982 were followed through 1990 (*3*). Cancer deaths were ascertained through the National Death Index and state mortality tapes, with the number of observed cancer deaths compared to the number expected based on U.S. general population mortality rates. All categories of causes of death and nearly all cancer site-specific risks were below unity, a pattern ascribed to the healthy worker effect in this relatively young cohort (median age in 1990 was 42 for men and 41 for women). Mortality analyses based on 7,354 deaths through 1990 and a subcohort mortality analysis of 1,103 technologists who were Catholic nuns revealed significantly elevated breast cancer risks among women who were first certified before 1940 and for a long time (30 or more years). However, risk was not related to the use of various commonly performed diagnostic or therapeutic procedures. Mortality risks were not elevated for any forms of leukemia or for lung cancer. Internal breast cancer mortality analyses conducted recently (through 1997) revealed increased risks for employment before 1950, and risk was also increased among women performing fluoroscopy or multi-film procedures before 1950 (compared to 1960 or later). In addition, the risk of acute, myeloid and monocytic leukemia combined was slightly, but not significantly, elevated for starting work before 1950 compared to 1960 or later.

Cancer Incidence Studies in Radiological Technologists

In Denmark, radiotherapy workers from two departments who were employed between 1954 and 1982 ($n = 4{,}151$) were followed from 1968 to 1985, and radiation doses were based on badge readings from monitoring that began in 1954 (*4*). The cumulative radiation dose was relatively low, with an average of 18 mSv. Cancers occurring in radiotherapy staff were ascertained by linking to the Danish Cancer Registry and expected cancers were calculated from Danish population rates. Only prostate cancer was statistically significantly elevated, but cancers of the breast, skin and brain and multiple myeloma were also somewhat increased. Cancer of the uterine cervix was about half of that expected. When the analyses were partitioned by dose categories, the relative risk estimates showed no discernable pattern, indicating low support for excess cancer risk in relation to occupational radiation exposure. Despite the small numbers of radiotherapy workers followed, the individual badge doses and the inclusion of women (82% of the cohort) are clearly study strengths.

A Canadian cohort of 191,000 radiation workers (including 110,000 dental and medical technologists) was assembled from dosimetry records spanning 1951 to 1988 (National Dose Registry of Canada) (*5*). Cancer incidence was determined by linkage with the Canadian Cancer Data Base over the years 1969–1988. Using Canadian population rates, standardized incidence ratios (SIRs) were computed. For males and females combined, nearly all SIRs were less than unity, including the leukemias and female breast cancer. The significantly increased SIRs for melanoma and thyroid cancer were somewhat difficult to explain, indicating that further evaluation was warranted. Internal cohort analyses revealed several elevated cancer site-specific excess relative risks (ERRs), including colon, rectum, pancreas, lung, testis, leukemia and all cancers in men. ERRs for women could not be reported separately because of a lack of numbers in the high-dose range. This cohort has badge doses for individual workers, an undisputed strength, but the cumulative doses are extremely low, yielding fairly high ERRs from internal analyses.

A cohort of medical X-ray workers in China was recently updated for cancer incidence between 1950 and 1995 (*6*). This study has followed 27,011 medical diagnostic X-ray workers and 25,782 medical specialists for cancer incidence using hospital employment records. Elevated risks were observed for leukemia, non-melanoma skin, female breast, lung, liver, bladder, esophagus and thyroid cancers. Slightly reduced risks were seen for oral cavity, colon/rectum and brain, but these did not achieve statistical significance. Work history characteristics supported conclusions that occupational radiation exposure was related to elevated risks of leukemia, skin, female breast and possibly thyroid cancers. In addition, physical and biological retrospective dose reconstruction was performed. Annual average doses were the highest before 1950 (~37 mGy/year) and dropped successively to ~3 mGy/year by 1975. Comparison of biological dosimetry (using translocation frequencies from FISH) and physical dosimetry revealed fairly good agreement, although the biological dosimetry consistently underestimated the reconstructed cumulative physical doses.

A large study of radiological technologists in the United States is ongoing, and investigators have recently completed a number of incident cancer analyses, which are not yet published. An overall cancer incidence analysis was based on 90,305 technologists who completed a postal survey in ~1984 and ~1995 or died in the interim. Self-reported cancers were verified by medical record review, for which 74% of records requested were obtained, and cancer reports were confirmed in 89%. Incident cancer occurrence was compared to that expected based on U.S. population rates from the NCI's Surveillance, Epidemiology and End Results Program. The incidence of solid cancers was elevated in women and lower than expected in men. Women had a significantly elevated incidence of breast cancer of about 1.2-fold. Among both sexes, melanoma and thyroid cancers were elevated and decreased risks were observed for buccal cavity/pharynx, rectum and lung cancers. The elevated risks of melanoma, breast and thyroid cancers suggest they could be related to radiation; however, the observed excesses may reflect, at least in part, increased screening in a population with easy access to health care.

From separate internal analyses, incident cancer risk at the sites of the female breast, non-melanoma skin cancer (basal cell), and melanoma are increased for work in earliest calendar period (before 1940) after adjustment for known risk factors. An increased incidence of thyroid cancer was associated with the practice of holding patients >50 times compared to <50 times for X-ray procedures, although risk was not significantly elevated among those working in the earliest years.

Summary

Overall, several studies suggest an elevated risk for cancers of the breast and thyroid and leukemia, with increasing risks for workers in early calendar periods. Non-melanoma skin cancer was increased among Chinese X-ray workers, but this cancer site is difficult to evaluate across cohorts if cancer registries do not routinely collect this information. There is some evidence for multiple myeloma and melanoma, but the latter has not been observed consistently. Some of the inconsistencies across studies could be due to choice of referent populations, risk estimates based on very low radiation doses for which confounding or bias (about which we may know little) accounts for observed associations, incomplete cancer ascertainment, and chance. With regard to radiation dosimetry, it is unlikely that good individual exposure data will ever be available for workers employed in calendar periods predating routine badge use (about 1950), yet these workers would be the most informative for risk assessment.

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